The Evolution of Carbon in the Chemical Industry

Josef R. Wünsch

BASF The Chemical Company, BASF SE,
GVM-J 550, D-67056 Ludwigshafen

Carbon, in its elemental state and in compounds, has been vital in developing and sustaining life on Earth. The rise of the industrial era is greatly owed to coal energy, and coal is still an important energy source. Several allotropes of elemental carbon are important for several industries due to their unique properties. For example: graphite, with its layered structure, high thermal stability and earth abundance, has been used as a lubricant and coating component since before modern times.

More complex compounds which are of utmost importance to us are also derived from carbon sources. The coal, next to its continued value as a major energy source, has been a source for synthetic hydrocarbons by Fischer Tropsch conversion which has become a commercial process by Sasol, South Africa. Coal and coal tars had been the origin of chemical development, i.e. tars were converted to the first industrial dyes, laying the foundation for BASF as a chemical company. Organic products that followed such as surface modifiers, food-additives and plastics have all derived from these carbon sources. Along with its role as an energy source, carbon in the graphite and activated carbon forms is also an important component of energy storage systems.

Carbon-based materials continue to be one focus of the rapid innovation within the chemical industry. Their use has evolved from additives for hardening rubber to high performance composites. Carbon fibers, with their impressive mechanical properties, ensure that composites are further developed for automotive and aeronautical sectors for their light weight and improved safety. Japanese companies, i.e. Toray have been leading the process of carbon fiber manufacturing. Polyacrylnitrile is the predominant source due to its excellent processability (spinning, oxidative stabilization, carbonization and graphitization). Many companies are covering the full value chain of carbon-fiber intermediates. BASF has partnered with SGL Carbon where both competencies are leveraged to address emerging markets in wind blade manufacturing or in automotive industries (BASFs' growth fields: Lightweight Composites, Energy management, Wind Energy). The major challenge to reduce "cost-per-part" must be resolved in order to allow penetration of CFRP into mass markets.

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On the electronics side, the increasing adoption of organic materials in new mobile technologies shows that sustainable sources can be used for high end consumer devices. Activated carbon, predominately gained market success as an active ingredient for filtration devices in water treatment, air & gas purification as well as processing in food, chemical and pharmaceutical industries. Due to its tunable surface – performance property, activated carbon is considered as material of choice for energy storage devices, i.e. Lithium Ion batteries, supercapacitors or fuel-cell applications. Certain features like high surface area, high packing density, low impurity content and low electrical resistance are focus of research development.

Development of carbons for the future needs of the chemical industry and society owe much to the contributions of researchers in the area. The discovery of the nanoscale forms: fullerenes, carbon nanotubes and graphene, show that there is a bright future for carbon. Professor Klaus Müllen has been driving those developments, having published pioneering syntheses of a wide variety of carbon derivatives and demonstrating equally diverse applications. Consequently, BASF has partnered with Professor Müllen and inaugurated the Carbon Materials Innovation Center (CMIC) for the research of advanced carbon-based solutions for the chemical industry in 2012. At CMIC, both pathways to graphene are explored, i.e. top-down by exfoliation from graphite using conventional techniques as well as bottom-up synthesis from distinct monomers to CVD process technologies for better control of property-performance relationship. The unique setup of CMIC allows immediate development and testing of devices, like modification of silicon anode materials by certain graphenic structures produced. First results showing enhanced cycle-rechargeability at interesting discharge capacities look extremely promising.